5. SUMMARY OF FORECAST VERIFICATION

5.1 ANNUAL FORECAST VERIFICATION

Verification of warning positions and intensities at initial, 24-, 48- and 72-hour forecast periods was made against the final best track. The (scalar) track forecast, along-track and cross-track errors (illustrated in Figure 5-1) were calculated for each verifying JTWC forecast. These data, in addition to a detailed summary for each tropical cyclone, is included as Chapter 6 (formerly Annex A). This section summarizes verification data for 1991 and contrasts it with annual verification statistics from previous years.

5.1.1 NORTH WEST PACIFIC OCEAN — The frequency distributions of errors for warning positions and 24-, 48- and 72-hour forecasts are presented in Figures 5-2A through 5-2D, respectively. Table 5-1 includes mean track, along-track and cross-track errors for 1978-1991. Figure 5-3 shows mean track errors and a 5-year moving average of track errors at 24-, 48- and 72-hours for the past 22 years. Table 5-2 lists annual mean track errors from 1959, when the JTWC was founded, until the present. Figure 5-4 illustrates JTWC intensity forecast errors at 24-, 48- and 72-hours for the past 22 years.

5.1.2 NORTH INDIAN OCEAN — The frequency distributions of errors for warning positions and 24-, 48- and 72-hour forecasts are presented in Figures 5-5A through 5-5D, respectively. Table 5-3 includes mean track, along-track and cross-track errors for 1971-1991. Figure 5-6 shows mean track errors and a 5-year moving average of track errors at 24-, 48- and 72-hours for the 21 years that the JTWC has issued warnings in the region.

5.1.3 SOUTH PACIFIC AND SOUTH INDIAN OCEANS — The frequency distributions of errors for warning positions and 24- and 48-hour forecasts are presented in Figures 5-7A through 5-7C, respectively. Table 5-4 includes mean track, along-track and cross-track errors for 1981-1991. Figures 5-8 shows mean track errors and a 5-year moving average of track errors at 24- and 48-hours for the 11 years that the JTWC has issued warnings in the region.

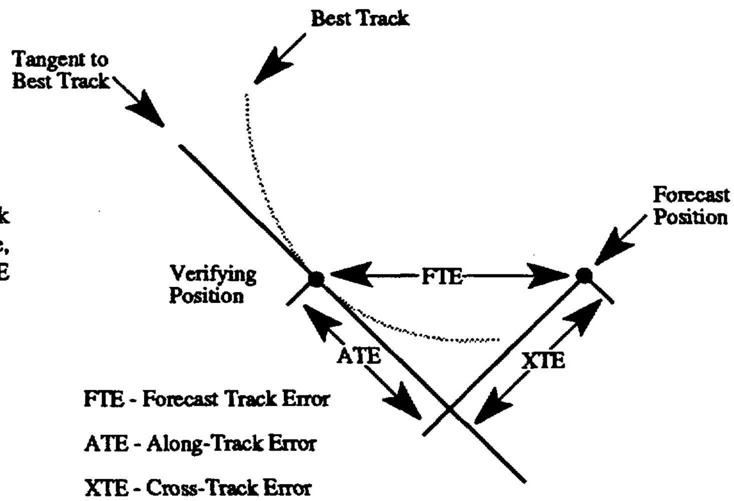

Figure 5-1. Definition of cross-track error (XTE), along-track error (ATE) and forecast track error (FTE). In this example, the XTE is positive (to the right of the best track) and the ATE is negative (behind or slower than the best track).

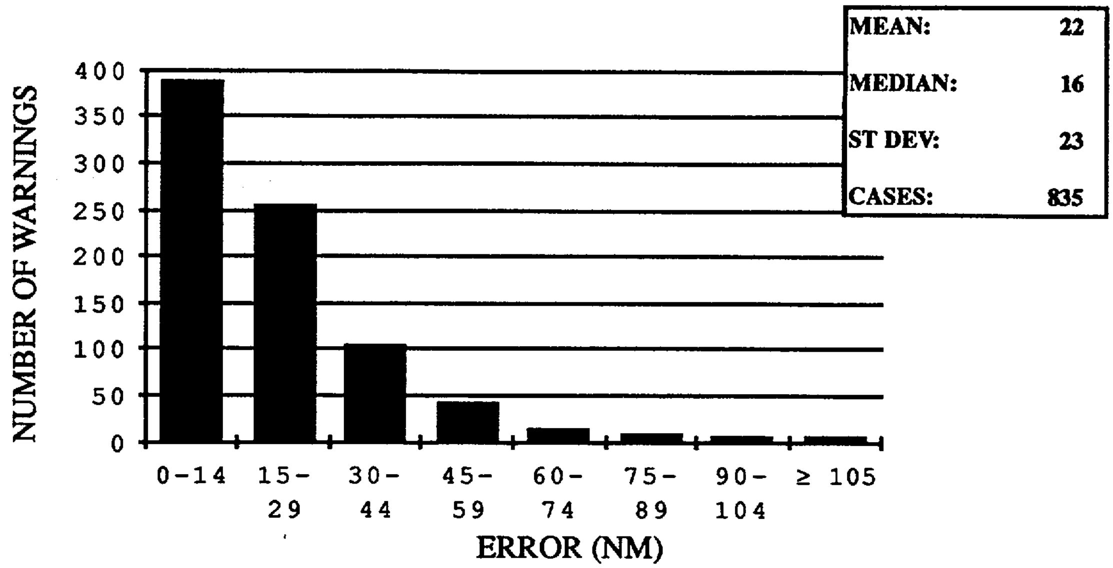

Figure 5-2A. Frequency distribution of initial position errors (15 nm increments) for the Northwest Pacific in 1991. The largest error during 1991 was 231 nm (Tropical Storm Luke (20W)).

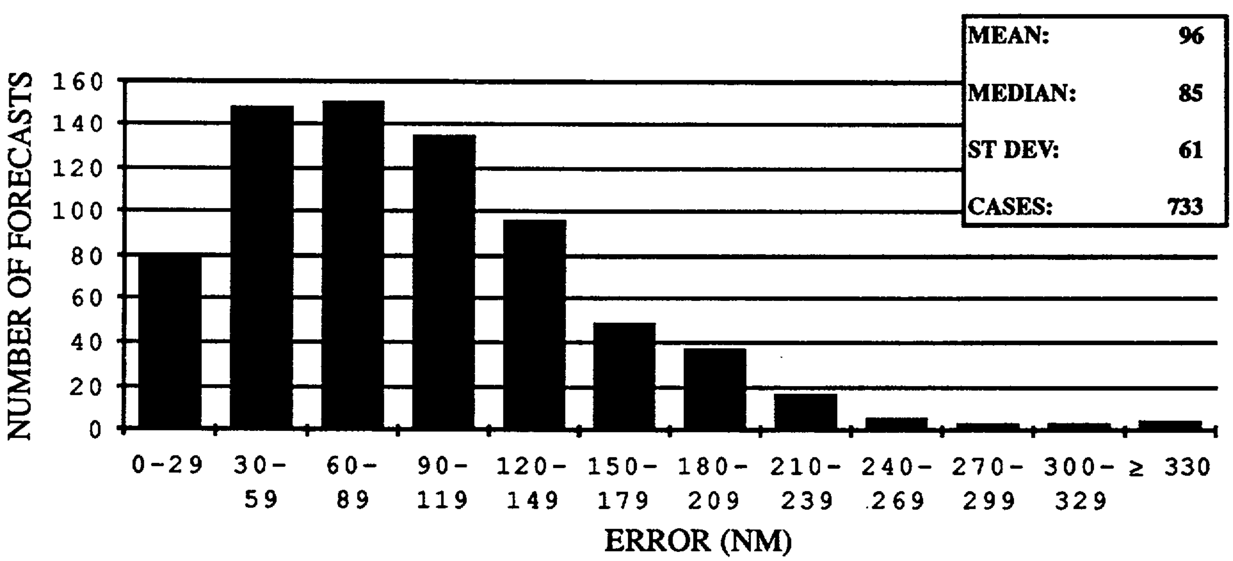

Figure 5-2B. Frequency distribution of 24-hour forecast errors (30 nm increments) for the Northwest Pacific in 1991. The largest error during 1991 was 403 nm (Tropical Storm Luke (20W)).

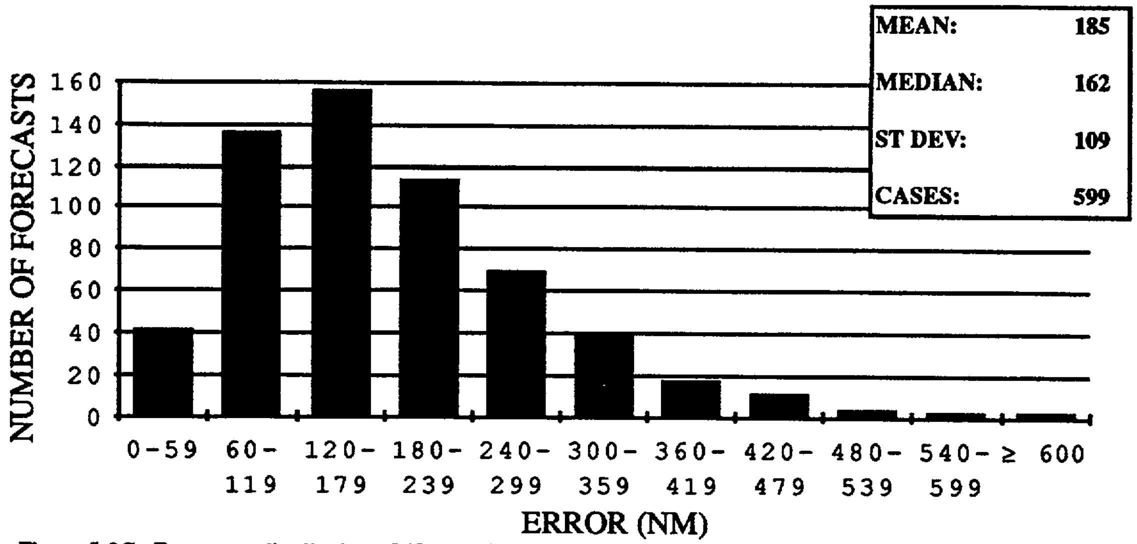

Figure 5-2C. Frequency distribution of 48-hour forecast errors (60 nm increments) for the Northwest Pacific in 1991. The largest error during 1991 was 860 nm (Tropical Storm Luke (20W)).

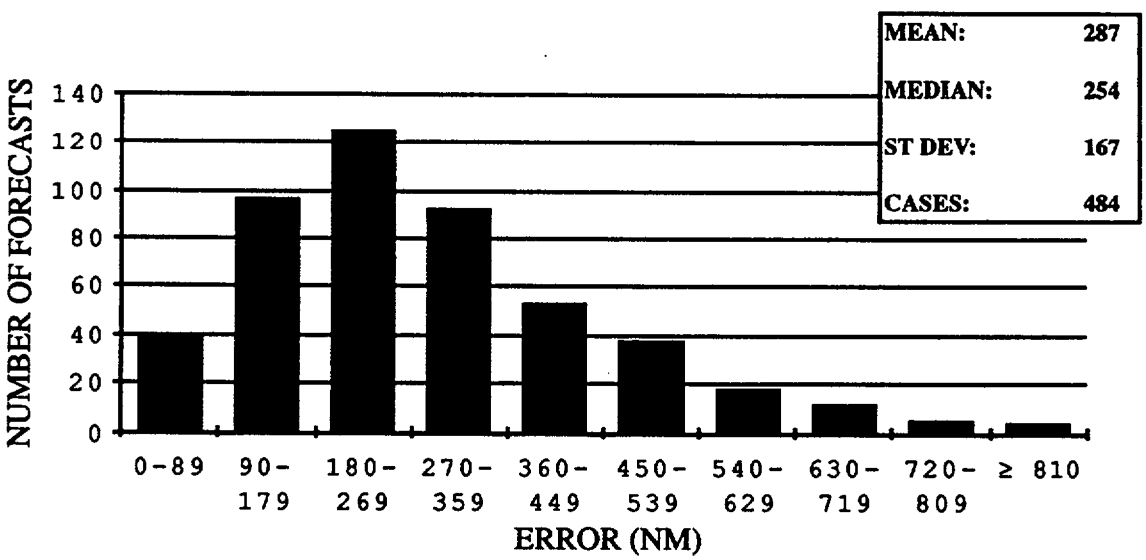

Figure 5-2D. Frequency distribution of 72-hour forecast errors (90 nm increments) for the Northwest Pacific in 1991. The largest error during 1991 was 912 nm (Super Typhoon Ruth (25W)).

TABLE 5-1. JTWC ANNUAL INITIAL POSITION AND FORECAST POSITION ERRORS (NM) 1978-1991 FOR THE NORTHWEST PACIFIC OCEAN

YEAR	NUMBER OF WARNINGS	INITIAL POSITION	24-HOUR NUMBER OF FORECASTS	24-HOUR TRACK	24-HOUR ALONG	24-HOUR CROSS	48-HOUR NUMBER OF FORECASTS	48-HOUR TRACK	48-HOUR ALONG	48-HOUR CROSS	72-HOUR NUMBER OF FORECASTS	72-HOUR TRACK	72-HOUR ALONG	72-HOUR CROSS
1978	696	21	556	126	87	71	420	274	194	151	295	411	296	218
1979	695	25	589	125	81	76	469	227	146	138	366	316	214	182
1980	590	28	491	127	86	76	369	244	165	147	267	391	266	230
1981	584	25	466	124	80	77	348	221	146	131	246	334	206	219
1972	786	19	666	113	74	70	532	238	162	142	425	342	223	211
1983	445	16	342	117	76	73	253	260	169	164	184	407	259	263
1984	611	22	492	117	84	64	378	232	163	131	286	363	238	216
1985	592	18	477	117	80	68	336	231	153	138	241	367	230	227
1986	743	21	645	126	85	70	535	261	183	151	412	394	276	227
1987	657	18	563	107	71	64	465	204	134	127	389	303	198	186
1988	465	23	373	114	85	58	262	216	170	103	183	315	244	159
1989	710	20	625	120	83	69	481	231	162	127	363	350	265	177
1990	794	21	658	120	81	70	404	237	162	138	305	355	242	211
1991	835	22	733	96	69	53	599	185	137	97	484	287	229	146
AVERAGE 78-91:	657	21	548	116	79	68	427	229	159	131	327	347	240	200

NOTE: Cross-track and along-track errors were adopted by the JTWC in 1986. Right-angle errors (used prior to 1986) were re-computed as cross-track and along-track errors after the fact to extend the data base. See Figure 5-1 for the definitions of cross-track and along-track errors.

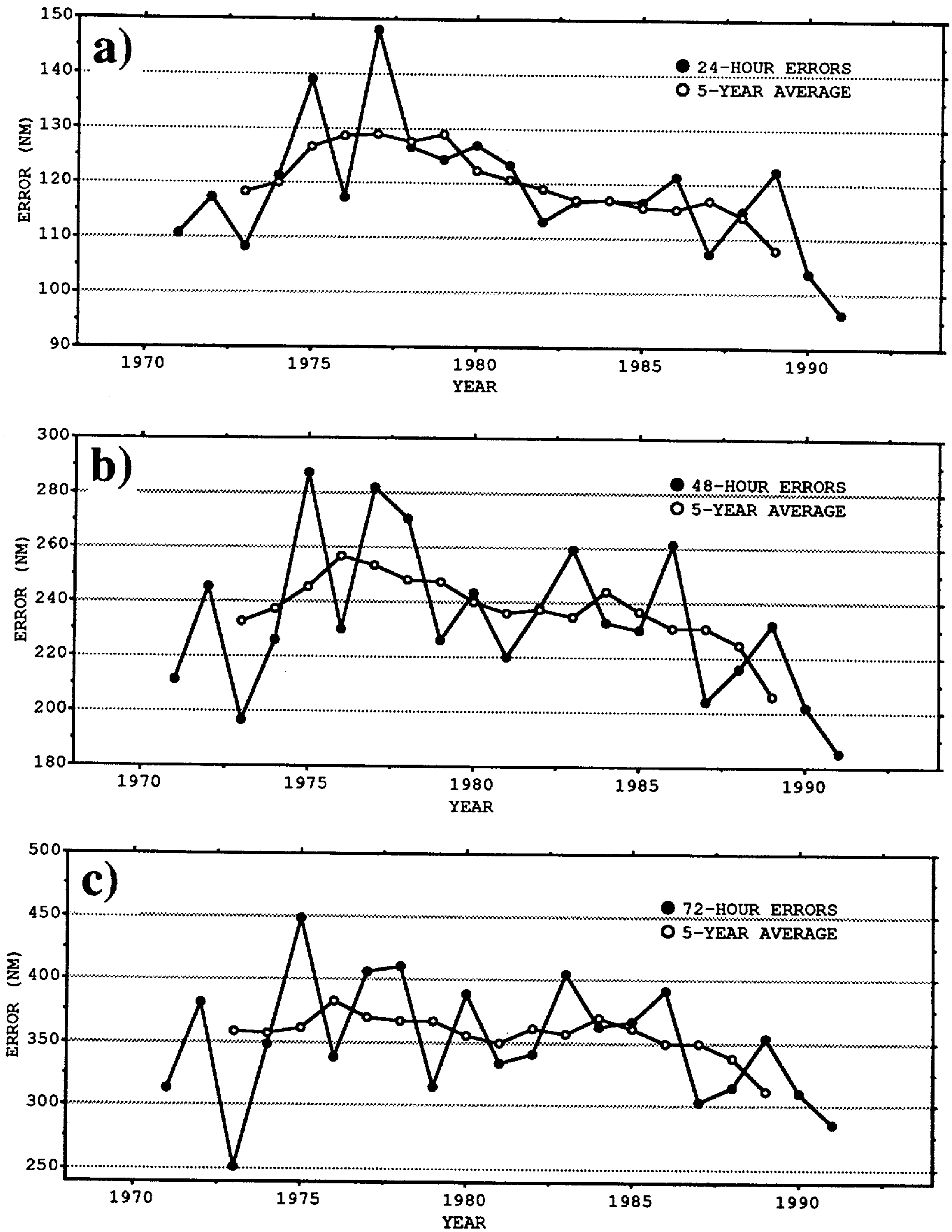

Figure 5-3. Annual mean track forecast errors (nm) and 5-year running mean for a) 24-hours, b) 48-hours and c) 72-hours in the Northwest Pacific Ocean.

TABLE 5-2

ANNUAL MEAN FORECAST ERRORS (NM)
NORTHWEST PACIFIC OCEAN

	24-HOUR		48-HOUR		72-HOUR	
YEAR	ALL	TYPHOONS*	ALL	TYPHOONS*	ALL	TYPHOONS*
1959		117**		267**		
1960		177**		354**		
1961		136		274		
1962		144		287		476
1963		127		246		374
1964		133		284		429
1965		151		303		418
1966		136		280		432
1967		125		276		414
1968		105		229		337
1969		111		237		349
1970	104	98	190	181	279	272
1971	111	99	212	203	317	308
1972	117	116	245	245	381	382
1973	108	102	197	193	253	245
1974	120	114	226	218	348	357
1975	138	129	288	279	450	442
1976	117	117	230	232	338	336
1977	148	140	283	266	407	390
1978	127	120	271	241	410	459
1979	124	113	226	219	316	319
1980	126	116	243	221	389	362
1981	123	117	220	215	334	342
1982	113	114	237	229	341	337
1983	117	110	259	247	405	384
1984	117	110	233	228	363	361
1985	117	112	231	228	367	355
1986	121	117	261	261	394	403
1987	107	101	204	211	303	318
1988	114	107	216	222	315	327
1989	120	107	231	214	350	325
1990	103	98	203	191	310	299
1991	96	93	185	187	286	298

* Forecasts were verified when the tropical cyclone intensities were at least 35 kt (18 m/sec).

** Forecast positions north of 35° north latitude were not verified.

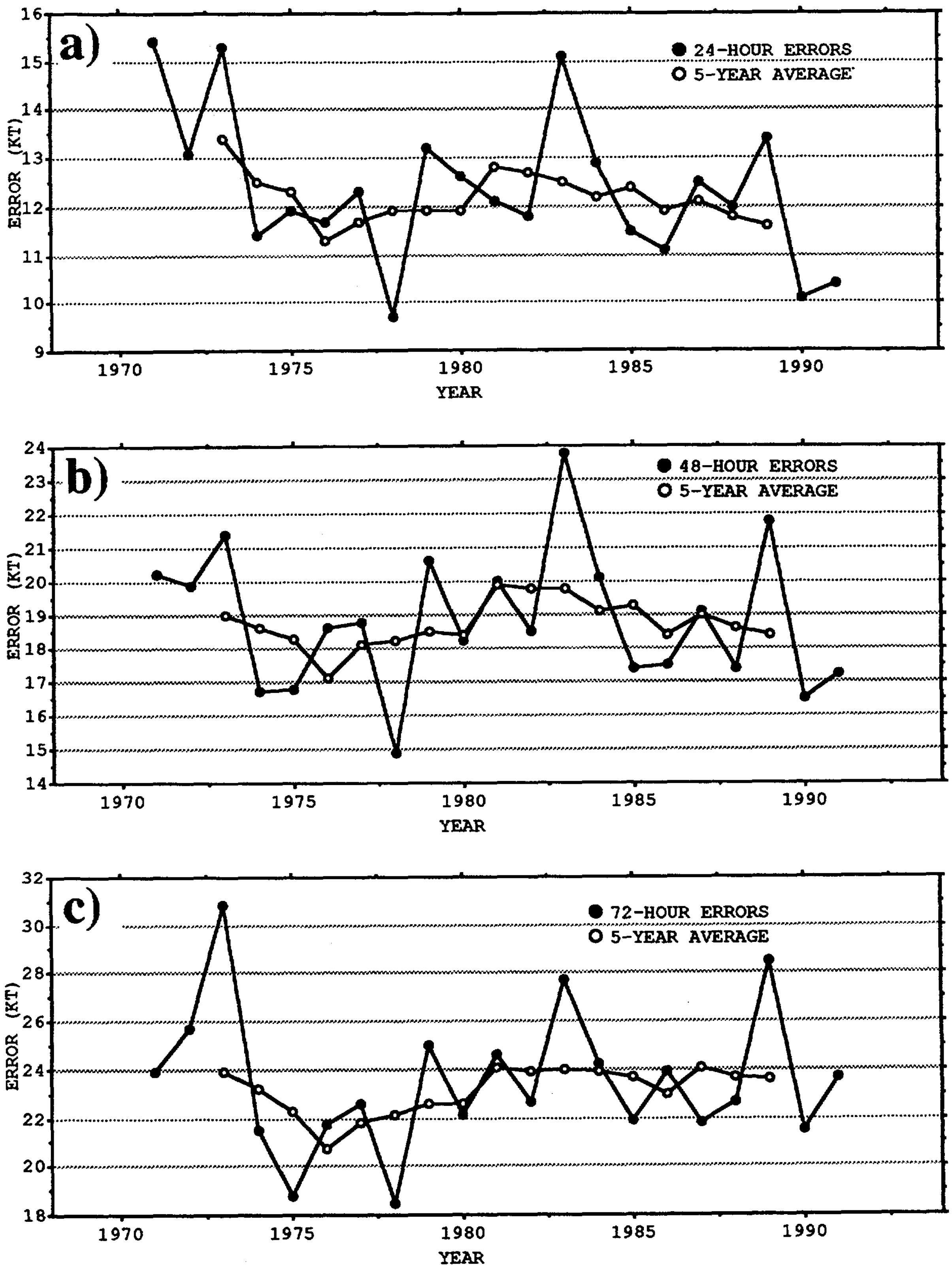

Figure 5-4. Annual mean intensity forecast errors (kt) and 5-year running mean for a) 24-hours, b)48-hours and c) 72-hours in the Northwest Pacific Ocean.

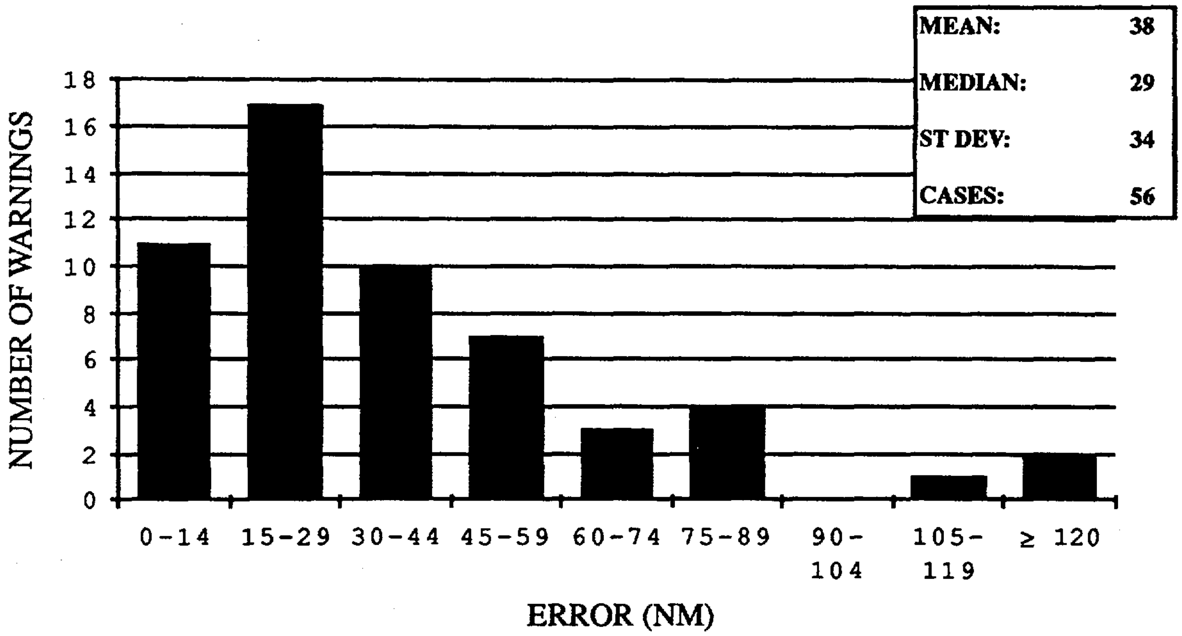

Figure 5-5A. Frequency distribution of initial positiont errors (15 nm increments) for the North Indian Ocean in 1991. The largest error during 1991 was 183 nm (Tropical Cyclone 01A).

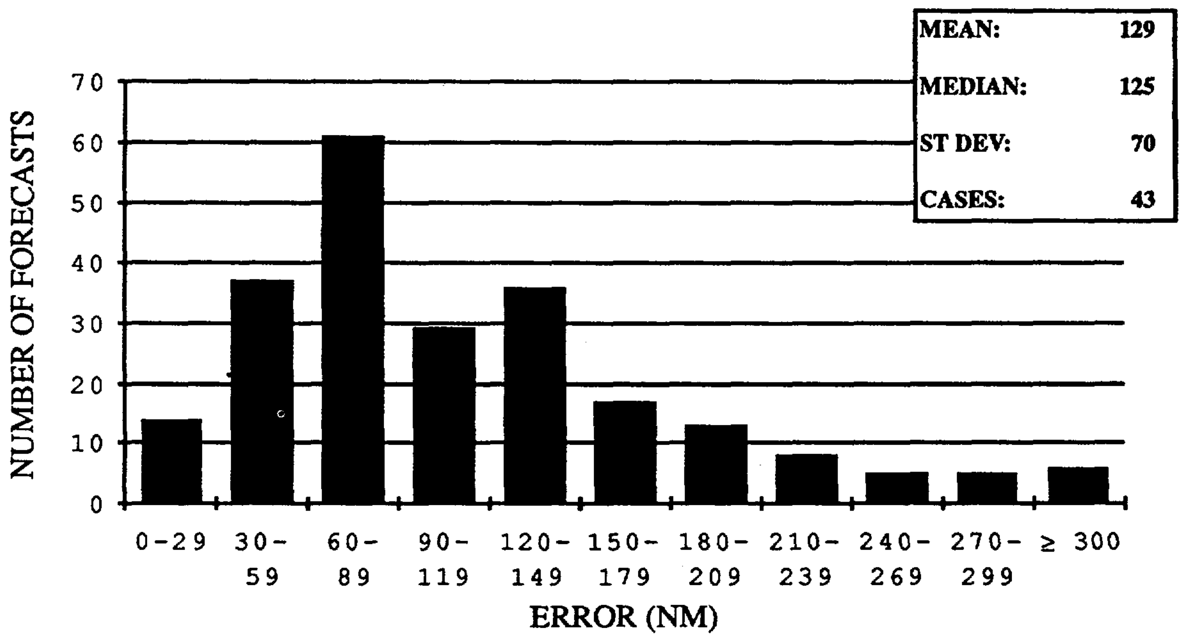

Figure 5-5B. Frequency distribution of 24-hour forecast errors (30 nm increments) for the North Indian Ocean in 1991. The largest error during 1991 was 307 nm (Tropical Cyclone 01A).

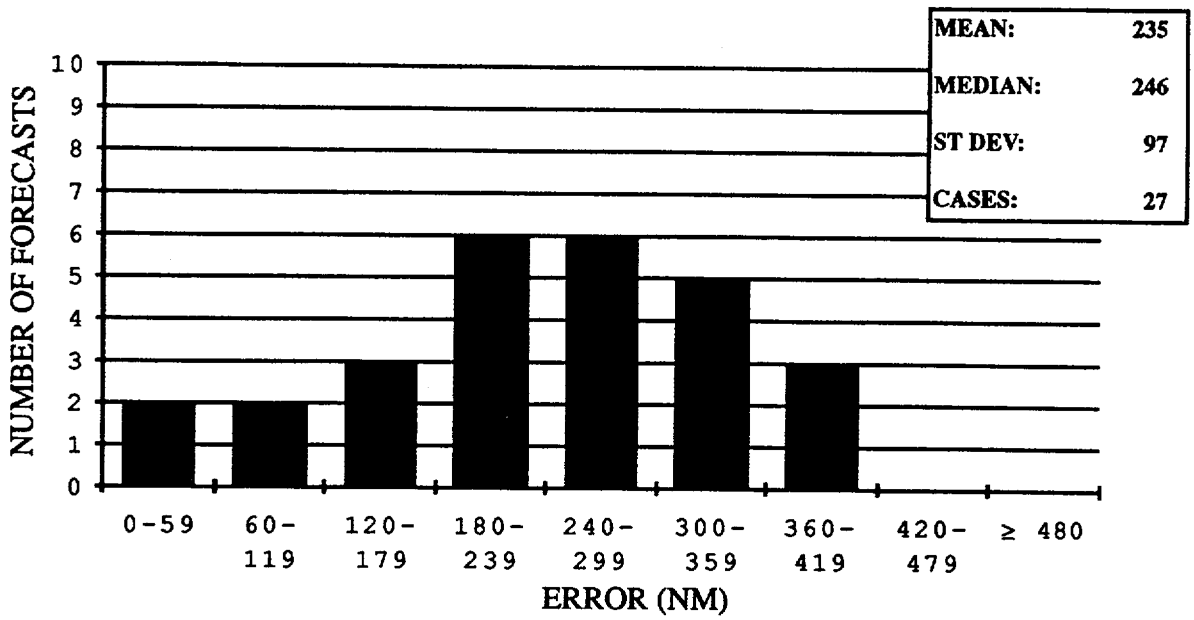

Figure 5-5C. Frequency distribution of 48-hour forecast errors (60 nm increments) for the North Indian Ocean in 1991. The largest error during 1991 was 409 nm (Tropical Cyclone 02B).

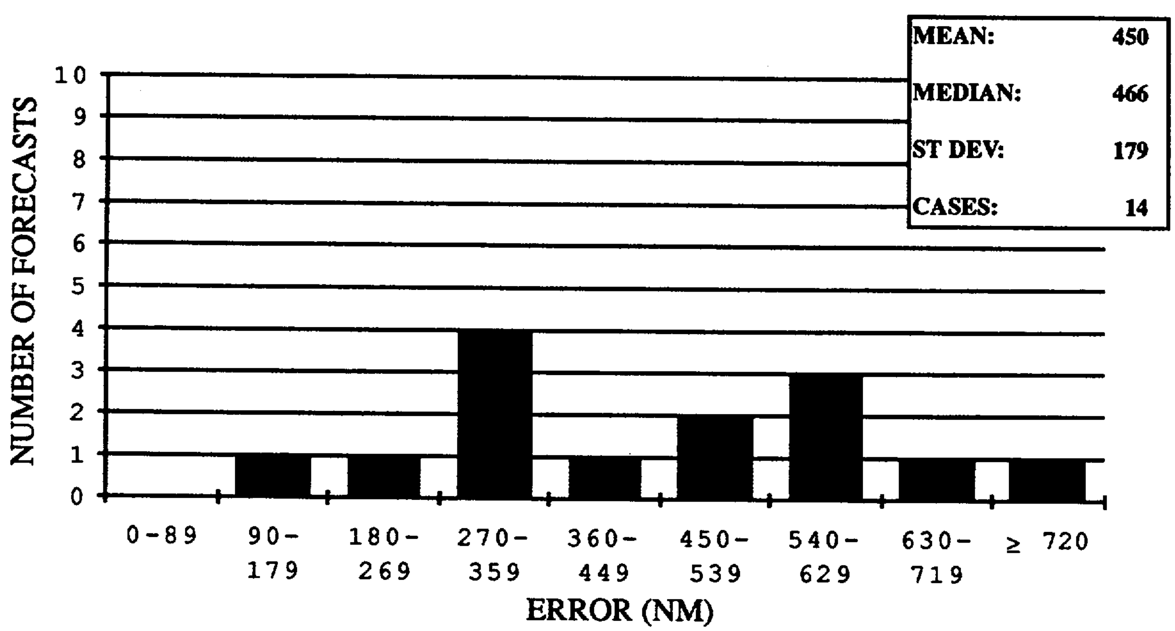

Figure 5-5D. Frequency distribution of 72-hour forecast errors (90 nm increments) for the North Indian Ocean in 1991. The largest error during 1991 was 722 nm (Tropical Cyclone 02B).

TABLE 5-3. JTWC ANNUAL INITIAL POSITION AND FORECAST POSITION ERRORS (NM) 1971-1991 FOR THE NORTH INDIAN OCEAN

YEAR	NUMBER OF WARNINGS	INITIAL POSITION	24-HOUR NUMBER OF FORECASTS	24-HOUR TRACK	24-HOUR ALONG	24-HOUR CROSS	48-HOUR NUMBER OF FORECASTS	48-HOUR TRACK	48-HOUR ALONG	48-HOUR CROSS	72-HOUR NUMBER OF FORECASTS	72-HOUR TRACK	72-HOUR ALONG	72-HOUR CROSS
1971	10	N/A	7	232	183	127	2	296	72	281	N/A			
1972	24	75	20	217	87	188	10	299	247	130	N/A			
1973	28	55	24	182	134	97	17	238	165	159	N/A			
1974	7	38	6	137	95	88	4	228	156	138	N/A			
1975	42	61	37	145	101	87	25	104	119	164	N/A			
1976	21	42	16	138	74	105	7	292	157	215	N/A			
1977	36	36	31	122	69	84	19	202	147	109	N/A			
1978	32	43	28	133	90	82	17	278	193	161	N/A			
1979	93	46	63	151	96	95	38	93	25	88	17	437	251	320
1980	14	41	7	115	81	71	2	176	120	109	1	167	97	137
1981	41	28	29	109	76	63	17	368	292	209	5	197	150	111
1982	55	35	37	138	110	68	18	153	137	53	7	762	653	332
1983	18	38	7	117	90	50	2	274	217	139	0			
1984	67	33	42	154	124	67	20	274	217	139	16	338	339	121
1985	53	31	30	122	102	53	8	242	119	194	0			
1986	28	52	16	134	118	53	7	168	131	80	5	269	189	180
1987	83	42	54	144	91	100	25	205	125	140	21	305	219	188
1988	44	34	30	120	89	63	18	219	112	176	12	409	227	303
1989	44	19	33	88	62	50	17	146	94	86	12	216	164	111
1990	46	31	36	101	85	43	24	146	117	67	17	185	130	104
1991	56	38	43	129	107	54	27	235	200	89	14	450	356	178
AVERAGE 71-91:	40	41	28	139	98	80	15	232	155	143	10	334	252	189

NOTE: Cross-track and along-track errors were adopted by the JTWC in 1986. Right-angle errors (used prior to 1986) were re-computed as cross-track and along-track errors after the fact to extend the data base. See Figure 5-1 for the definitions of cross-track and along-track errors.

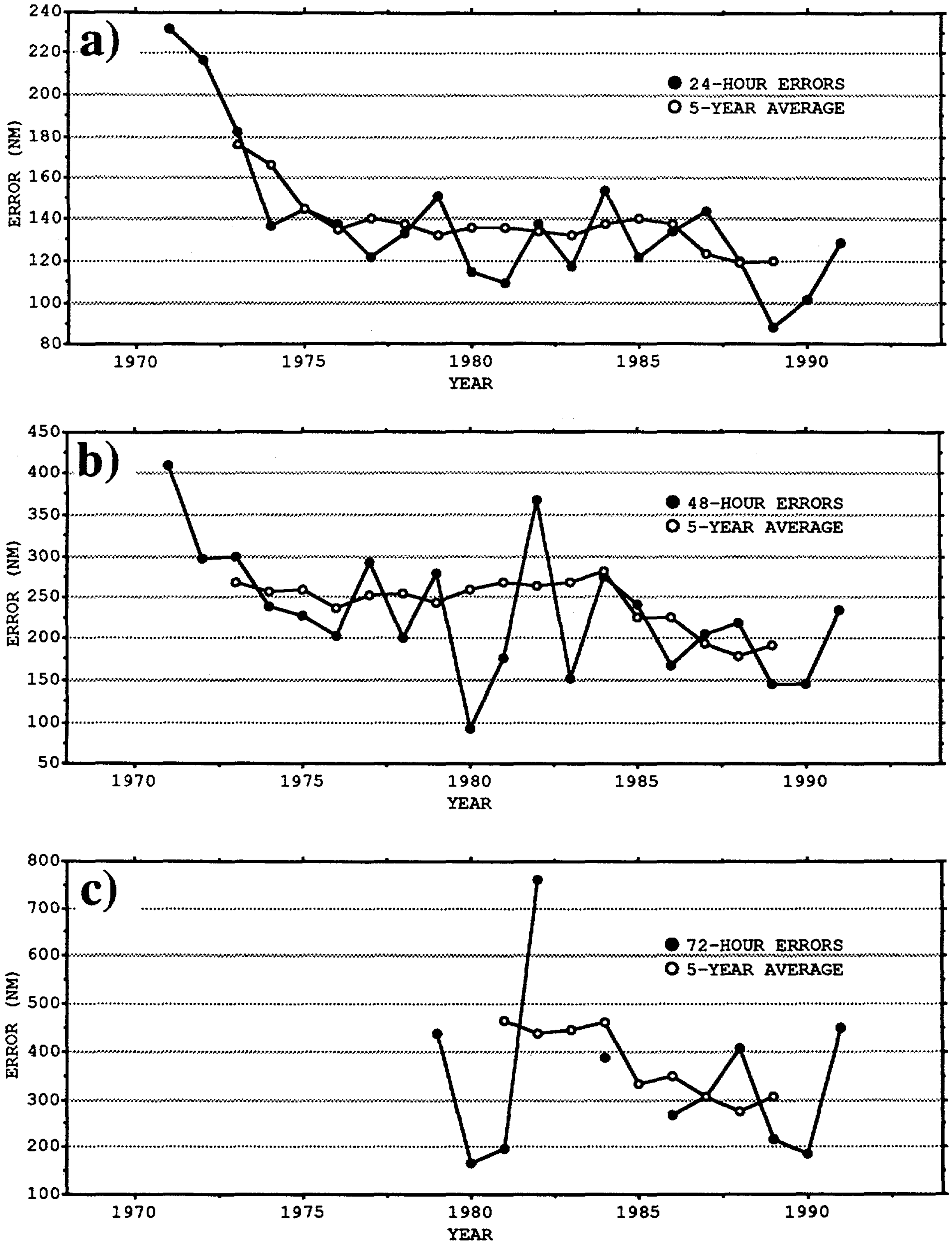

Figure 5-6. Annual mean track errors (nm) and 5-year running mean for a) 24-hours, b) 48-hours and c) 72-hours in the North Indian Ocean. Note that no 72-hour forecasts verified prior to 1979, in 1983 and 1985.

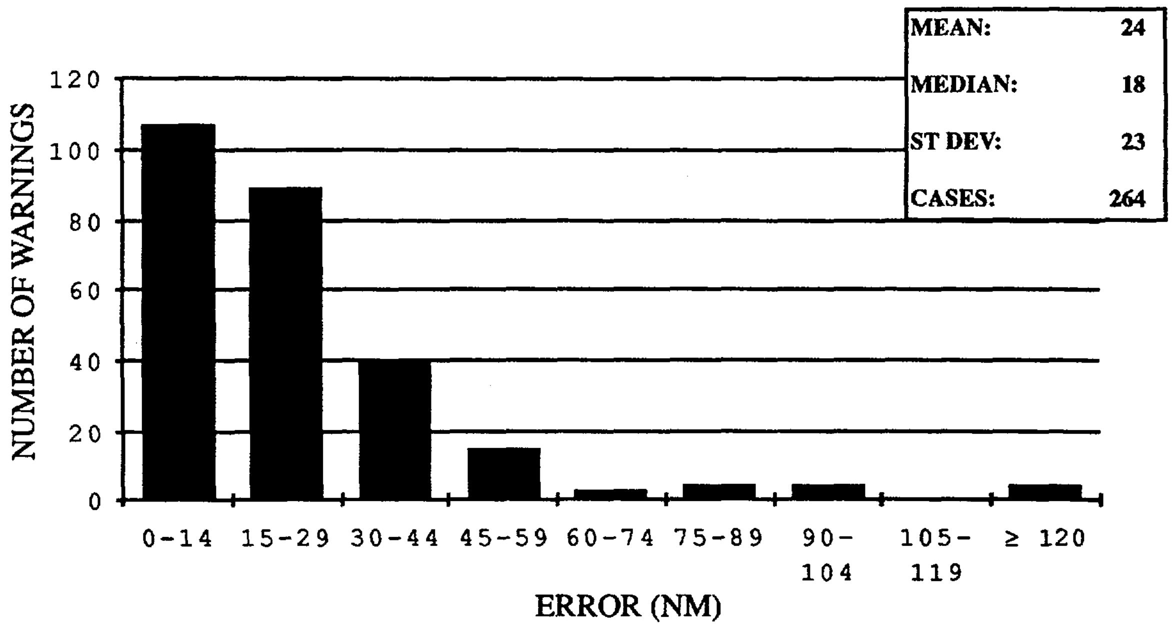

Figure 5-7A. Frequency distribution of initial position errors (15 nm increments) for the South Pacific and South Indian Ocean in 1991. The largest error during 1991 was 154 nm (Tropical Cyclone 08S).

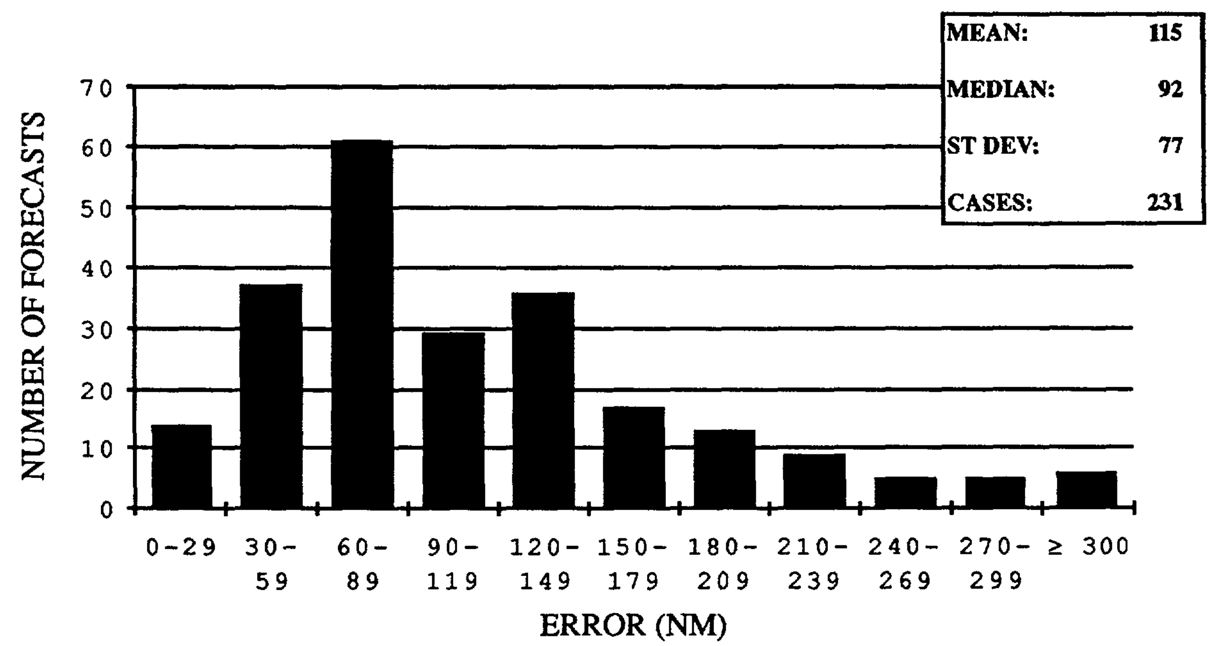

Figure 5-7B. Frequency distribution of 24-hour forecast errors (30 nm increments) for the South Pacific and South Indian Ocean in 1991. The largest error during 1991 was 386 nm (Tropical Cyclone 12S).

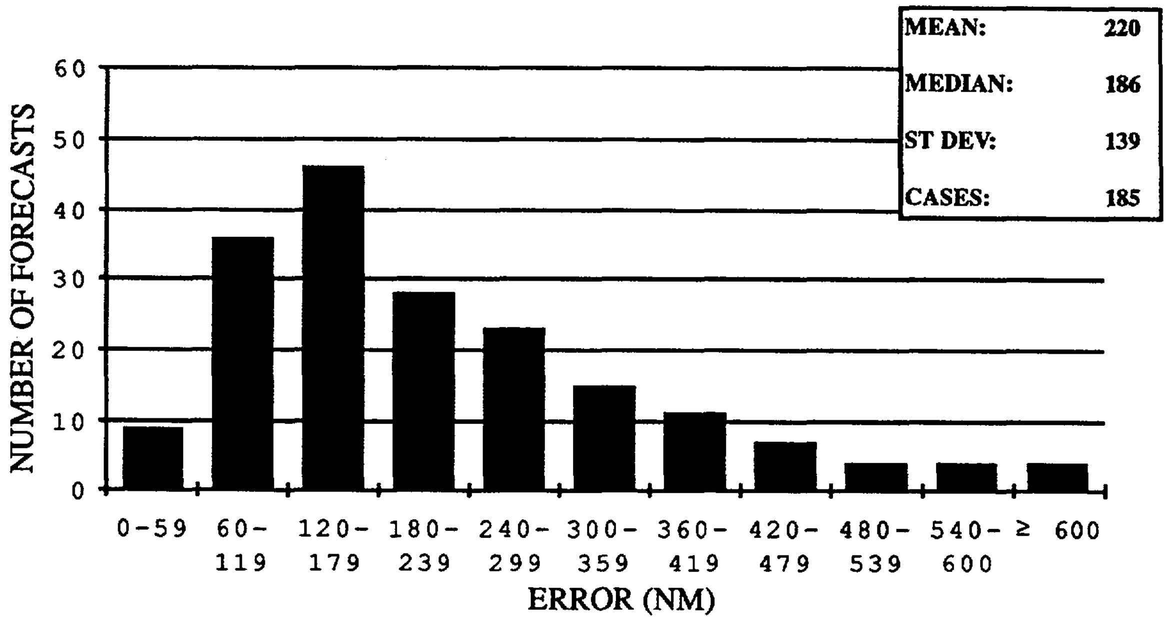

Figure 5-7C. Frequency distribution of 48-hour forecast errors (60 nm increments) for the South Pacific and South Indian Ocean in 1991. The largest error during 1991 was 716 nm (Tropical Cyclone 17S).

TABLE 5-4. JTWC ANNUAL INITIAL POSITION AND FORECAST POSITION ERRORS (NM) 1981-1991 FOR THE SOUTHERN HEMISPHERE

YEAR	NUMBER OF WARNINGS	INITIAL POSITION	NUMBER OF FORECASTS	24-HOUR TRACK	24-HOUR ALONG	24-HOUR CROSS	NUMBER OF FORECASTS	48-HOUR TRACK	48-HOUR ALONG	48-HOUR CROSS
1981	226	48	190	165	103	106	140	315	204	201
1982	275	38	238	144	98	86	176	274	188	164
1983*	191	35	163	130	88	77	126	241	158	145
1984	301	36	252	133	90	79	191	231	159	134
1985*	306	36	257	134	92	79	193	236	169	132
1986*	279	40	227	129	86	77	171	262	169	164
1987*	189	46	138	145	94	90	101	280	153	138
1988*	204	34	99	146	98	83	48	290	246	144
1989*	287	31	242	124	84	73	186	240	166	136
1990*	272	27	228	143	105	74	177	263	178	152
1991	264	24	231	115	75	69	185	220	152	129
AVERAGE 78-91:	254	36	206	136	92	80	255	255	175	150

NOTE: Cross-track and along-track errors were adopted by the JTWC in 1986. Right-angle errors (used prior to 1986) were re-computed as cross-track and along-track errors after the fact to extend the data base.

See Figure 5-1 for the definitions of cross-track and along-track errors.

* These statistics are for JTWC forecasts only. NWOC errors are not included.

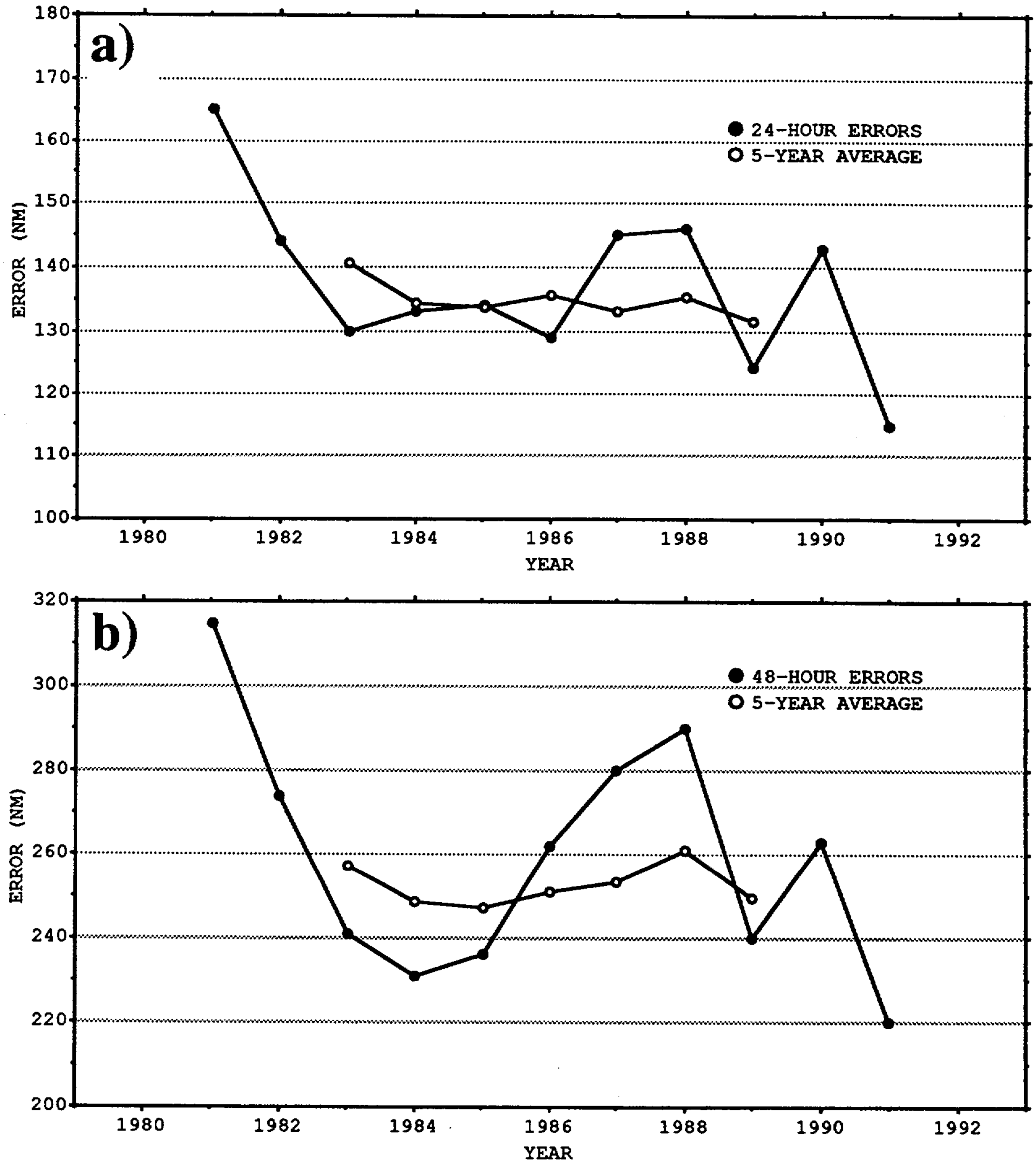

Figure 5-8. Annual mean track forecast errors and the 5-year running mean for a) 24-hours and b) 48-hours in the South Pacific and South Indian Oceans.

5.2 COMPARISON OF OBJECTIVE TECHNIQUES

JTWC uses a variety of objective techniques for guidance in the warning development process. Multiple techniques are required, because each technique has particular strengths and weaknesses which vary by basin, numerical model initialization, time of year, synoptic situation and forecast period. The accuracy of objective aid forecasts depends on both the specified position and the past motion of the tropical cyclone as determined by the working best track. JTWC initializes its objective techniques using the extrapolated warning position.

An initiative is presently underway to convert most of the objective techniques that currently run on mainframe computers at FNOC to desktop computer versions that run on ATCF workstations. These will eventually replace the FNOC-generated techniques. Three of these new aids have been received and are under evaluation.

Unless stated otherwise, all the objective techniques discussed below run in all basins covered by JTWC's AOR and provide forecast positions at 24-, 48-, and 72-hours unless the technique aborts prematurely during computations. The techniques can be divided into six general categories: extrapolation, climatology and analogs, statistical, dynamic, hybrids, and empirical or analytical.

5.2.1 EXTRAPOLATION (XTRP) — Past speed and direction are computed using the rhumb line distance between the current and 12-hour old positions of the tropical cyclone. Extrapolation from the current warning position is used to compute forecast positions.

5.2.2 CLIMATOLOGY and ANALOGS

5.2.2.1 CLIMATOLOGY (CLIM) — Employs time and location windows relative to the current position of the storm to determine which historical storms will be used to compute the forecast. The historical data base is 1945-1981 for the Northwest Pacific, and 1900 to 1990 for the rest of JTWC's AOR. A second climatology-based technique exists on JTWC's Macintosh®™ II computers. It employs data bases from 1945 to 1991 and from 1970 to 1991. The latter is referred to as the satellite-era data base. Objective intensity forecasts are available from these data bases. Scatter diagrams of expected tropical cyclone motion at bifurcation points are also available from these data bases.

5.2.2.2 ANALOGS — JTWC's analog and climatology techniques use the same historical data base, except that the analog approach imposes more restrictions on which storms will be used to compute the forecast positions. Analogs in all basins must satisfy time, location, speed, and direction windows, although the window definitions are distinctly different in the Northwest Pacific. In this basin, acceptable analogs are also ranked in terms of a similarity index that includes the above parameters and: storm size and size change, intensity and intensity change, and heights and locations of the 700-mb subtropical ridge and upstream midlatitude trough. In other basins, all acceptable analogs receive equal weighting and a persistence bias is explicitly added to the forecast. Inside the Northwest Pacific, analog weighting is varied using the similarity index, and a persistence bias is implicitly incorporated by rotating the analog tracks so that they initially match the 12-hr old motion of the current storm. In the Northwest Pacific, a forecast based on all acceptable analogs called TOTL, as well as a forecast based only on historical recurvers called RECR are available. Outside this basin, only the TOTL technique is available.

5.2.3 STATISTICAL

5.2.3.1 CLIMATOLOGY AND PERSISTENCE (CLIP)

(CLIP) — A statistical regression technique that is based on climatology, current position and 12-hour and 24-hour past movement. This technique is used as a crude baseline against which to measure the forecast skill of other more sophisticated techniques. CLIP in the Northwest Pacific uses third-order regression equations and is based on the work of Xu and Neumann (1985). CLIP has been available outside this basin since mid-1990, with regression coefficients recently recomputed by FNOC based on the updated 1900-1989 data base.

5.2.3.2 COLORADO STATE UNIVERSITY MODEL (CSUM)

MODEL (CSUM) — A statistical-dynamical technique based on the work of Matsumoto (1984). Predictor parameters include the current and 24-hr old position of the storm, heights from the current and 24-hr old NOGAPS 500-mb analyses, and heights from the 24-hr and 48-hr NOGAPS 500 mb prognoses. Height values from 200-mb fields are substituted for storms that have an intensity exceeding 90 knots and are located north of the subtropical ridge. Three distinct sets of regression equations are used depending on whether the storm's direction of motion falls into "below," "on," or "above" the subtropical ridge categories. During the development of the regression equation coefficients for CSUM, the so-called "perfect prog" approach was used, in which verifying analyses were substituted for the numerical prognoses that are used when CSUM is run operationally. Thus, CSUM was not "tuned" to any particular version of NOGAPS, and in fact, the performance of CSUM should presumably improve as new versions of NOGAPS improve. CSUM runs only in the Northwest Pacific, South China Sea, and North Indian Ocean basins.

5.2.4 DYNAMIC

5.2.4.1 NOGAPS VORTEX TRACKING ROUTINE (NGPS) — This objective technique follows the movement of the point of minimum height on the 1000 mb pressure surface analyzed and predicted by NOGAPS. A search in the expected vicinity of the storm is conducted every six hours through 72 hours, even if the tracking routine temporarily fails to discern a minimum height point. Explicit insertion of a tropical cyclone bogus via data provided over TYMNET by JTWC began in mid-1990, and should improve the ability of the NOGAPS technique to track the vortex.

5.2.4.2 ONE-WAY INFLUENCE TROPICAL CYCLONE MODEL (OTCM) — This technique is a coarse resolution (205 km grid), three layer, primitive equation model with a horizontal domain of 6400 x 4700 km. OTCM is initialized using 6-hour or 12-hour prognostic fields from the latest NOGAPS run, and the initial fields are smoothed and adjusted in the vicinity of the storm to induce a persistence bias into OTCM's forecast. A symmetric bogus vortex is then inserted, and the boundaries updated every 12 hours by NOGAPS fields as the integration proceeds. The bogus vortex is maintained against frictional dissipation by an analytical heating function. The forecast positions are based on the movement of the vortex in the lowest layer of the model (effectively 850-mb).

5.2.4.3 FNOC BETA AND ADVECTION MODEL (FBAM) — This model is an adaptation of the Beta and Advection model used by NMC. The forecast motion results from a calculation of environmental steering and an empirical correction for the observed vector difference between that steering and the 12-hour old storm motion. The steering is computed from the NOGAPS Deep Layer Mean (DLM) wind fields which are a weighted average of the wind fields computed for the 1000-mb to 100-mb levels. The difference between past storm motion and the DLM steering is treated as if the storm were a Rossby wave with an "effective radius" propagating in response to the horizontal gradient of the coriolis parameter, Beta. The forecast proceeds in one-hour steps, recomputing the effective radius as Beta changes with storm latitude, and blending in a persistence bias for the first 12 hours.

5.2.5 HYBRIDS

5.2.5.1 HALF PERSISTENCE AND CLIMATOLOGY (HPAC) — Forecast positions are generated by equally weighting the forecasts given by XTRP and CLIM.

5.2.5.2 COMBINED CONFIDENCE WEIGHTED FORECASTS (CCWF) — An optimal blend of objective techniques produced by the ATCF. The ATCF blends the selected techniques (currently OTCM, CSUM and HPAC) by using the inverse of the covariance matrices computed from historical and real-time cross-track and along-track errors as the weighting function.

5.2.6 EMPIRICAL OR ANALYTICAL

5.2.6.1 DVORAK — An estimation of a tropical cyclone's current and 24-hour forecast intensity is made from the interpretation of satellite imagery (Dvorak, 1984) . These intensity estimates are used with other intensity related data and trends to forecast short-term tropical cyclone intensity.

5.2.6.2 MARTIN/HOLLAND — The technique adapts an earlier work (Holland, 1980) and specifically addresses the need for realistic 30-, 50- and 100-kt(15-,26- and 51-m/sec) wind radii around tropical cyclones. It solves equations for basic gradient wind relations within the tropical cyclone area, using input parameters obtained from enhanced infrared satellite imagery. The diagnosis also includes an asymmetric area of winds caused by tropical cyclone movement. Satellite-derived size and intensity parameters are also used to diagnose internal steering components of tropical cyclone motion known collectively as "beta-drift".

5.2.6.3 TYPHOON ACCELERATION PREDICTION TECHNIQUE (TAPT) — This technique (Weir, 1982) utilizes upper-tropospheric and surface wind fields to estimate acceleration associated with the tropical cyclone's interaction with the mid-latitude westerlies. It includes guidelines for the duration of acceleration, upper limits and probable path of the cyclone.

5.3 TESTING AND RESULTS

A comparison of selected techniques is included in Table 5-5 for all Northwest Pacific tropical cyclones; Table 5-6 for all North Indian Ocean tropical cyclones and Table 5-7 for the Southern Hemisphere. In these tables, "x-axis" refers to techniques listed vertically. For example (Table 5-8) in the 743 cases available for a (homogeneous) comparison, the average forecast error at 24 hours was 111 nm (205 km) for CSUM and 117 nm (216 km) for FBAM. The difference of 6 nm (11 km) is shown in the lower right. (Differences are not always exact, due to computational round-off which occurs for each of the cases available for comparison).

TABLE 5-5

1991 ERROR STATISTICS FOR SELECTED OBJECTIVE TECHNIQUES IN THE NORTHWEST PACIFIC (1 JAN 1991 - 31 DEC 1991)

24-HOUR MEAN FORECAST ERROR (NM)

	JTWC		NGPS		OTCM		CSUM		FBAM		CLIP		HPAC	
JTWC	733	**96**												
	96	0												
NGPS	270	96	272	**138**										
	137	41	138	0										
OTCM	686	95	259	137	761	**116**								
	118	23	113	-24	116	0								
CSUM	706	96	261	136	741	116	778	**112**						
	113	17	112	-24	111	-5	112	0						
FBAM	692	95	257	137	722	115	743	111	759	**117**				
	118	23	128	-9	115	0	117	6	117	0				
CLIP	722	96	270	138	760	116	778	112	759	117	798	**118**		
	118	22	116	-22	117	1	118	6	116	-1	118	0		
HPAC	717	96	268	137	753	116	771	112	752	117	791	118	792	**128**
	129	33	128	-9	127	11	128	16	127	10	128	10	128	0

Number of Cases	X-Axis Technique Error
Y-Axis Technique Error	Error Difference (Y-X)

48-HOUR MEAN FORECAST ERROR (NM)

	JTWC		NGPS		OTCM		CSUM		FBAM		CLIP		HPAC	
JTWC	599	**185**												
	185	0												
NGPS	202	187	207	**221**										
	221	34	221	0										
OTCM	532	182	189	225	618	**194**								
	198	16	196	-29	194	0								
CSUM	579	185	198	215	603	194	663	**212**						
	217	32	222	7	210	16	212	0						
FBAM	570	183	194	221	588	194	634	213	649	**211**				
	216	33	233	12	208	14	211	-2	211	0				
CLIP	593	185	205	222	617	194	663	212	649	211	680	**232**		
	236	51	241	19	231	37	232	20	232	21	232	0		
HPAC	589	184	203	221	613	195	658	212	643	211	674	232	675	**242**
	248	64	245	24	239	44	242	30	243	32	242	10	242	0

72-HOUR MEAN FORECAST ERROR (NM)

	JTWC		NGPS		OTCM		CSUM		FBAM		CLIP		HPAC	
JTWC	484	**287**												
	287	0												
NGPS	123	292	127	**323**										
	321	29	323	0										
OTCM	394	276	108	323	476	**277**								
	283	7	292	-31	277	0								
CSUM	471	289	122	317	465	277	553	**308**						
	316	27	333	16	292	15	308	0						
FBAM	461	285	118	326	453	277	529	311	539	**316**				
	325	40	335	9	296	19	318	7	316	0				
CLIP	480	287	125	323	475	276	553	308	539	316	565	**350**		
	354	67	373	50	346	70	351	43	352	36	350	0		
HPAC	480	287	125	323	473	277	551	308	537	316	563	351	564	**361**
	373	86	387	64	335	58	363	55	363	47	361	10	361	0

JTWC - JTWC Forecast
OTCM - One-Way Tropical Cyclone Model
FBAM - FNOC Beta and Advection Model
HPAC - Half Persistence and Climatology
NGPS - Navy-Operational Global-Atmospheric Prediction System
CSUM - Colorado State University Model
CLIP - Climatology/Persistence

TABLE 5-6

1991 ERROR STATISTICS FOR SELECTED OBJECTIVE TECHNIQUES IN THE NORTH INDIAN OCEAN (1 JAN 1991 - 31 DEC 1991)

Number of Cases	X-Axis Technique Error
Y-Axis Technique Error	Error Difference (Y-X)

24-HOUR MEAN FORECAST ERROR (NM)

	JTWC		OTCM		FBAM		CLIP		HPAC		TOTL		CLIM	
JTWC	43	**129**												
	129	0												
OTCM	40	125	45	**133**										
	131	6	133	0										
FBAM	40	125	45	133	45	**154**								
	146	21	154	21	154	0								
CLIP	40	125	45	133	45	154	45	**150**						
	151	26	150	17	150	-4	150	0						
HPAC	35	110	40	125	40	152	40	134	40	**130**				
	130	20	130	5	130	-22	130	-4	130	0				
TOTL	31	120	34	130	34	155	34	128	31	121	34	**148**		
	146	26	148	18	148	-7	148	20	138	17	148	0		
CLIM	35	110	40	125	40	152	40	134	40	130	31	138	40	**123**
	122	12	123	-2	123	-29	123	-11	123	-7	116	-22	123	0

48-HOUR MEAN FORECAST ERROR (NM)

	JTWC		OTCM		FBAM		CLIP		HPAC		TOTL		CLIM	
JTWC	27	**235**												
	235	0												
OTCM	23	230	28	**258**										
	259	29	258	0										
FBAM	25	233	28	258	30	**272**								
	257	24	270	12	272	0								
CLIP	25	233	28	258	30	272	30	**277**						
	274	41	282	24	277	5	277	0						
HPAC	23	228	26	252	28	259	28	271	28	**224**				
	233	5	228	-24	224	-35	224	-47	224	0				
TOTL	16	245	16	261	18	232	18	261	18	237	18	**285**		
	271	26	280	19	285	53	285	24	285	48	285	0		
CLIM	23	228	26	252	28	259	28	271	28	224	18	285	28	**207**
	210	-18	217	-35	207	-52	207	-64	207	-17	199	-86	207	0

72-HOUR MEAN FORECAST ERROR (NM)

	JTWC		OTCM		FBAM		CLIP		HPAC		TOTL		CLIM	
JTWC	14	**450**												
	450	0												
OTCM	12	470	15	**471**										
	513	43	471	0										
FBAM	14	450	15	471	17	**321**								
	284	-166	324	-147	321	0								
CLIP	14	450	15	471	17	321	17	**412**						
	402	-48	429	-42	412	91	412	0						
HPAC	13	464	13	483	15	283	15	383	15	**386**				
	410	-54	401	-82	386	103	386	3	386	0				
TOTL	9	468	7	553	9	311	9	419	9	419	9	**472**		
	472	4	468	-85	472	161	472	53	472	53	472	0		
CLIM	13	464	13	483	15	283	15	383	15	386	9	472	15	**327**
	296	-168	373	-110	327	44	327	-56	327	-59	313	-159	327	0

JTWC - JTWC Forecast
FBAM - FNOC Beta and Advection Model
HPAC - Half Persistence and Climatology
CLIM - Climatology
OTCM - One-Way Tropical Cyclone Model
CLIP - Climatology/Persistence
TOTL - Total Analog

TABLE 5-7

1991 ERROR STATISTICS FOR SELECTED OBJECTIVE TECHNIQUES IN THE SOUTHERN HEMISPHERE (1 JUL 1990 - 30 JUN 1991)

24-HOUR MEAN FORECAST ERROR (NM)

	JTWC		OTCM		CLIP		HPAC		TOTL		CLIM		XTRP	
JTWC	232	118												
	118	0												
OTCM	204	116	266	124										
	122	6	124	0										
CLIP	215	118	260	124	278	163								
	156	38	153	29	163	0								
HPAC	213	116	256	121	271	158	273	135						
	132	16	134	13	135	-23	135	0						
TOTL	140	112	172	129	185	158	185	135	185	138				
	135	23	135	6	138	-20	138	3	138	0				
CLIM	214	116	260	122	271	158	273	135	185	138	277	164		
	155	39	160	38	164	6	164	29	166	28	164	0		
XTRP	211	120	256	125	272	164	267	137	184	138	267	166	274	147
	146	26	144	19	147	-17	143	6	134	-4	143	-23	147	0

Number of Cases	X-Axis Technique Error
Y-Axis Technique Error	Error Difference (Y-X)

48-HOUR MEAN FORECAST ERROR (NM)

	JTWC		OTCM		CLIP		HPAC		TOTL		CLIM		XTRP	
JTWC	186	**223**												
	223	0												
OTCM	152	227	208	**229**										
	230	3	229	0										
CLIP	172	224	204	230	233	**269**								
	263	39	256	26	269	0								
HPAC	171	219	203	228	229	264	231	**240**						
	238	19	233	5	240	-24	240	0						
TOTL	114	218	131	252	153	268	152	245	153	**267**				
	266	48	268	16	267	-1	267	22	267	0				
CLIM	171	219	205	228	229	264	231	240	152	267	233	**275**		
	260	41	262	34	275	11	275	35	288	21	275	0		
XTRP	169	227	200	232	227	271	225	243	152	268	225	278	229	**284**
	287	60	283	51	284	13	279	36	262	-6	279	1	284	0

72-HOUR MEAN FORECAST ERROR (NM)

	OTCM		CLIP		HPAC		TOTL		CLIM		XTRP	
OTCM	160	**342**										
	342	0										
CLIP	157	342	190	**350**								
	337	-5	350	0								
HPAC	158	341	188	352	190	**338**						
	331	-10	337	-15	338	0						
TOTL	93	374	118	348	118	359	118	**406**				
	418	44	406	58	406	47	406	0				
CLIM	159	343	188	352	190	338	118	406	191	**372**		
	377	34	370	18	370	32	401	-5	372	0		
XTRP	154	344	185	353	185	343	117	407	185	373	187	**425**
	419	75	424	71	427	84	405	-2	427	54	425	0

JTWC - JTWC Forecast
CLIP - Climatology/Persistence
TOTL - Total Analog
XTRP - Extrapolation
OTCM - One-Way Tropical Cyclone Model
HPAC - Half Persistence and Climatology
CLIM - Climatology

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